

State of California

**Technical Support Document - Part A**  
**Proposed Identification of**  
**Environmental Tobacco Smoke as a**  
**Toxic Air Contaminant**



*California Environmental Protection Agency*

*Air Resources Board*

*Office of Environmental Health Hazard Assessment*



**Air Resources Board**  
**Stationary Source Division**  
**Air Quality Measures Branch**

March 2005

**State of California  
AIR RESOURCES BOARD**

**Technical Support Document for the  
“Proposed Identification of Environmental Tobacco Smoke  
as a Toxic Air Contaminant”**

**PART A**

California Environmental Protection Agency  
Air Resources Board  
Office of Environmental Health Hazard Assessment

This report, prepared by the staff of the Air Resources Board (ARB), contains the staff's evaluation of exposures to environmental tobacco smoke in California. This report is referred to as Part A of the technical support document, Proposed Identification of Environmental Tobacco Smoke as a Toxic Air Contaminant. The Office of Environmental Health Hazard Assessment prepared the health assessment, or Part B, of the report.

## ACKNOWLEDGMENTS

This report was prepared with the help of many other staff from the Air Resources Board. We particularly thank the following people for their contributions during the development of this report: Tony Servin, Michael Benjamin, Chris Nguyen, Vivian Lerch, Jose Saldana, Marline Hicks, Steven Yee, Dennis Goodenow, Steve Aston – Air Resources Board.

We would like to especially thank Dr. Katharine Hammond of the University of California, Berkeley for her technical expertise and review during the development of the ETS nicotine monitoring protocol used for our ETS monitoring study. We also thank Dr. Matthew Hengel of the University of California, Davis for his technical expertise in development of the ETS sample nicotine analysis techniques.

We would also like to express our deep appreciation for the help of the staff from the Los Angeles and Ventura County's Tobacco Control Sections for their expertise and funding for our ETS air monitoring study. Without their help and funding, a quantifiable assessment based on outdoor California exposures may not have been possible.

### Project Leads

Robert Krieger  
Jim Stebbins

### Contributing Authors

Susie Chung  
Lynn Baker  
Peggy Jenkins  
David Julian  
Susan Lum  
Judy Polakoff (OEHHA)  
Dorothy Shimer  
Bruce Winder (OEHHA)

### Reviewed and Approved by:

Stationary Source Division  
Peter Venturini, Division Chief  
Bob Barham, Assistant Division Chief  
Janette Brooks, Chief, Air Quality Measures Branch  
Jim Aguila, Manager, Substance Evaluation Section

## TABLE OF CONTENTS

		<u>Page</u>
I.	Introduction	I-1
II.	Summary	II-1
III.	Chemical and Physical Properties of ETS	III-1
	A. ETS as a Complex Mixture	III-1
	1. Mainstream Smoke	III-3
	2. Sidestream Smoke	III-3
	3. Differences in the Composition of Mainstream And Sidestream Smoke	III-4
	B. Gas Phase Components in ETS	III-6
	C. Particulate Matter Components in ETS	III-7
	1. ETS Particle Size and Distribution	III-9
	D. Semi-Volatile Components in ETS - Nicotine	III-17
	E. References	III-19
IV.	Production, Uses, Sources, Emissions, and Smoking Trends	IV-1
	A. Production	IV-1
	B. Uses	IV-1
	C. Sources of Emissions	IV-2
	1. ETS "Point Source"	IV-2
	2. Smoking Prevalence in California	IV-4
	D. ETS Emissions	IV-7
	1. ETS Emissions by Region	IV-8
	2. Comparing California and Total U.S. ETS Emissions	IV-9
	3. ETS Emissions by Age	IV-10
	E. ETS Emissions Projection	IV-11
	F. References	IV-13
V.	Exposure to Environmental Tobacco Smoke	V-1
	A. California Activity Patterns and ETS Exposure	V-2
	B. Prevalence of ETS Exposure in California	V-3
	C. Monitoring for ETS	V-5
	1. ETS Markers	V-5
	2. Ambient Air Monitoring Studies for ETS	V-6
	3. ARB's Ambient ETS Monitoring Study	V-7
	4. Modeled Ambient Concentrations for ETS	V-9
	5. Estimated Los Angeles Outdoor Annual Average Ambient ETS Concentrations	V-10
	D. Indoor Air Concentrations of ETS	V-11

## TABLE OF CONTENTS (con't)

	<u>Page</u>
1. Introduction	V-11
2. Indoor Air Concentrations of ETS Based on Nicotine Measurements	V-13
3. Indoor Air Concentrations Based on ETS-Associated Respirable Particulate Matter	V-23
4. Indoor Air Concentrations Based on Measurement of Other ETS Constituents	V-34
5. ETS Concentrations in Vehicles	V-36
6. Modeling Studies to Estimate Indoor Air Concentrations of ETS	V-37
7. Summary of Indoor Data	V-39
E. Exposure Estimation Scenarios	V-42
1. Introduction	V-42
2. Background and Calculations	V-42
3. Scenarios	V-43
4. Summary and Conclusions	V-54
F. Biological Markers of Exposure to ETS	V-57
1. Introduction	V-57
2. Introduction to Biomarkers of ETS Exposure	V-58
3. Analytical Methods for Nicotine/Cotinine	V-61
4. Biomarkers: Carbon Monoxide and Carboxyhemoglobin	V-71
5. Biomarkers: Thiocyanate	V-71
6. Biomarkers: Protein and DNA Adducts	V-71
7. Biomarkers: Other	V-73
8. Biomarkers and Children	V-73
9. Summary and Conclusions	V-78
G. References	V-80
VI. Atmospheric Persistence	VI-1
A. Atmospheric Reactions of Gaseous Species	VI-1
B. Atmospheric Reactions of Particulate Species	VI-2
C. Nicotine	VI-3
D. Tobacco-Specific N-Nitrosamines	VI-4
E. PAH and PAH-Derivatives	VI-4
F. References	VI-7
Appendix A. List of Known ETS Constituents	
Appendix B. ETS Emissions Calculation Methodology	
Appendix C. ARB ETS Air Monitoring Study	
Appendix D. Estimated Urban Ambient ETS Concentration	

## LIST OF TABLES

<b><u>Content</u></b>	<b><u>Page</u></b>
Table III-1: Distribution of Constituents in Fresh, Undiluted Mainstream Smoke and Diluted Sidestream Smoke From Nonfiltered Cigarettes	III-4
Table III-2: Gas Phase Components in ETS with Known Health Effects	III-7
Table III-3: Constituents of Particulate Matter in ETS with Known Health Effects	III-8
Table III-4: Reported ETS Particle Sizes	III-11
Table III-5: Effects of Primary Dilution Ratio on the Number Concentration and Particle Size Distribution of Mainstream Cigarette Smoke	III-15
Table IV-1: Comparison of FTC and Actual Cigarette CO Emissions	IV-2
Table IV-2: Current Adult and Adolescent Prevalence (%)	IV-6
Table IV-3: 2002 California Statewide ETS Emissions (Tons/Year)	IV-8
Table IV-4: California vs. U.S. ETS Emissions	IV-9
Table IV-5: 2002 California Adult and Adolescent Cigarette Consumption (millions)	IV-10
Table IV-6: Adult vs. Adolescent Cigarette ETS Emissions (Tons/Year)	IV-10
Table V-1: Percent of Time Californians Spend in Major Locations	V-2
Table V-2: Prevalence of ETS Exposure in California	V-5
Table V-3: Results of ARB Nicotine Air Monitoring Adjacent to Outdoor Smoking Areas	V-9
Table V-4: Estimates of ETS Outdoor Ambient Concentrations	V-11
Table V-5: Summary of Indoor Nicotine Concentrations in Smoking Environments Before 1996	V-15&16
Table V-6: Summary of Indoor Nicotine Concentrations in Smoking Environments After 1995	V-19-22
Table V-7: Summary of Indoor Particulate Matter Concentrations in Smoking Environments Before 1996	V-24

## LIST OF TABLES (con't)

<b><u>Content</u></b>	<b><u>Page</u></b>
Table V-8: Summary of Indoor Particulate Matter Concentrations in Smoking Environments After 1995	V-29-33
Table V-9: Estimates of Current Indoor Concentrations of Nicotine and RSP	V-41
Table V-10: Summary of Outdoor Nicotine Concentration Data Used in the Estimation of Scenario-Based Exposure	V-44
Table V-11: Summary of Nicotine Exposure Scenario Results	V-55
Table V-12: Nicotine Concentrations in Inhaled Air with Corresponding Salivary Cotinine Concentrations	V-64
Table V-13: Effect of Home Versus Work Smoking Environment on Exposure to ETS	V-65
Table V-14: Seasonal Effect on ETS Exposure	V-65
Table V-15: Effect of Home Versus Work Smoking Environment on Exposure to ETS	V-66
Table V-16: Job-Related Cotinine and Nicotine Measured Concentrations	V-70
Table V-17: Concentrations of NNAL, NNAL-Gluc, and Total Cotinine (mean $\pm$ SD) in the Urine of Elementary School-aged Children	V-77
Table VI-1: Estimated Atmospheric Lifetimes of Selected ETS Constituents	VI-2
Table VI-2: PAHs Detected in ETS	VI-5
Table VI-3: Estimated Atmospheric Lifetimes of Selected PAHs	VI-5

## LIST OF FIGURES

<b><u>Content</u></b>	<b><u>Page</u></b>
Figure III-1: Diagram of a Cigarette	III-2
Figure III-2: Air Flux During Smoking	III-2
Figure III-3: Size Distribution of ETS Particles	III-10
Figure III-4: ETS Particle Concentration Over Time	III-12
Figure III-5: ETS Particle Distribution Temporal Effect (0.015-0.75 $\mu\text{m}$ size range)	III-13
Figure III-6: Effect of Aging on Particle Size – Coagulation	III-13
Figure III-7: Evaporation of Particles in Sidestream Tobacco Smoke	III-14
Figure III-8: Particle Formation in Cigarette Smoke Gases	III-16
Figure III-9: Three forms of Nicotine	III-18
Figure IV-1: Adult and Adolescent Smoking Prevalence in California (1990-1999)	IV-5
Figure IV-2: Regional ETS Emissions From Cigarettes	IV-9
Figure IV-3: Cigarette Distributions in California	IV-11
Figure V-1: Distribution of Serum Cotinine Levels in the US Population Aged 4 Years and Older	V-67
Figure V-2: Distribution of Serum Cotinine Levels in the US Population Aged 4 Years and Older by Tobacco Use	V-68
Figure V-3: Cotinine Concentrations Based on Cigarette Consumption	V-69
Figure VI-1: Nicotine Conversion	VI-4